Manganese

Most manganese in soils is precipitated as manganese oxide or hydroxide. The form available to plants is the Mn^{2+} ion. Manganese availability is related more to soil pH than soil test manganese levels. Manganese recommendations are based on the crop being grown and soil pH. On low pH mineral soils (pH less than 4.8), manganese can be toxic to plants. A few suspected deficiencies have been reported in fruit and vegetable crops grown on alkaline mineral soils. Manganese deficiency problems are most likely to occur on organic soils with a pH greater than 5.8. Soil and foliar application rates of manganese based on crop and soil pH are presented in **Table 43** (organic soils). If crops grown on mineral soils show signs of manganese deficiency or have low tissue manganese levels, a foliar application at the rate of 0.2 lb Mn/A is recommended. Two or three applications are usually required. Apply with 50 to 100 gallons of water per acre. Chelated sources of manganese are recommended for foliar spays.

Molybdenum

Molybdenum is available to plants as the MoO_4^{2-} ion. Deficiencies may occur on acid sandy soils and acid peats. Certain vegetable crops such as cauliflower are particularly susceptible to molybdenum deficiency. Soil tests for molybdenum are not reliable for making molybdenum fertilizer recommendations. Liming soils to a pH of 6.0-6.5 is the best method to correct molybdenum deficiency; however, some cauliflower cultivars seem to be susceptible to molybdenum deficiency even in limed soils. Soil applications of 0.25-0.5 pounds per acre of actual molybdenum can be used if molybdenum deficiency is a problem. Foliar applications of 1-2 oz/A of actual molybdenum are suggested for cole crops where a deficiency is known or expected. Do not overapply molybdenum as high rates can be toxic to animals.

Nickel

Nickel has only recently been shown to be an essential nutrient for plants. The form of nickel available to plants is the Ni^{2+} ion. Deficiencies of nickel have not been reported in field soils in Minnesota; however, some plants (for example, river birch) grown in peat based potting media are susceptible to nickel deficiency. High levels of zinc seem to accentuate nickel deficiency. Soil tests for nickel have not yet been calibrated. Actual requirements for nickel are low and adequate levels of nickel are believed to be present in most soils, although further research is necessary to actually determine nickel requirements of field grown crops in Minnesota. For potted plants showing nickel deficiency, drenches with solutions containing 3 to 6 ppm nickel as nickel nitrate, chloride, or sulfate can correct the problem. High levels of nickel can be toxic to plants. Elevated nickel levels are sometimes found in sewage sludge.

Zinc

The form of zinc available to plants is the Zn^{2+} ion. Zinc deficiency can occur on alkaline soils and sandy soils low in organic matter. High levels of phosphorus coupled with low levels of soil zinc may induce zinc deficiency. If zinc deficiency is known or suspected, zinc sulfate can be blended with a dry bulk fertilizer. Application rates of zinc based on a soil test are presented in **Table 44**. Zinc applied in the row should not come in contact with the seed. For crops showing zinc deficiency during the growing season, foliar applications of zinc chelate (2 oz/A actual zinc) are suggested.

Table 44. *Zinc recommendations for all fruit and vegetable crops.*

Soil Zinc Test	Relative Level	Zinc to Apply Broadcast	Zinc to Apply Row
ppm		------------- lb/A	----------------
0 - 0.5	low	10	2
0.6 - 1.0	medium	5	1
1.1+	high	0	0

Procedures Used in the University of Minnesota Soil Testing Laboratory

The following analyses are offered:

1. Estimated texture category⁺
2. Total organic matter (%)* (loss on ignition), maximum amount measured is 99.9%
3. Soil pH⁺ (1:1, water:soil suspension)
4. Lime requirement⁺ (SMP buffer index)
5. Extractable phosphorus⁺ (Bray-P1 extractant, Olsen-P sodium bicarbonate extractant)
6. Exchangeable potassium⁺ (ammonium acetate extractant)
7. Soluble salts* (electrical conductivity, 1:1 soil suspension, saturation extract)
8. Extractable sulfur* (calcium phosphate extractant)
9. Extractable zinc* (DTPA extractant)
10. Extractable zinc, copper, iron, and manganese* (DTPA extractant)
11. Nitrate-nitrogen* (0.01 *M* $CaSO_4$ extractant)
12. Exchangeable magnesium and calcium* (ammonium acetate extractant)
13. Hot water extractable boron* (0.1% $CaCl_2 \cdot 2H_2O$ extractant)

⁺ Tested routinely
* Tested only on request

Sample Preparation

At the laboratory, each sample is assigned a number, transferred to a paper bag, and then placed in a metal tray. Every 12th sample is a quality control sample, either a check sample of known chemical properties to ensure accuracy, or a duplicate sample to evaluate laboratory precision.

Samples are dried in a cabinet equipped with a heating element and an exhaust fan to remove moisture-laden air. The temperature in the cabinet does not exceed 104°F in order to approximate air-drying conditions.

Samples are crushed with a mechanical grinder equipped with a porcelain mortar and stainless-steel auger. They are subsequently passed through a stainless-steel 10-mesh sieve to remove larger clods and unwanted debris. Crushed and sieved samples are dried overnight before analysis.

Texture and Organic Matter

The relative amounts of sand, silt, and clay are estimated by the feel of the soil in a moist condition. The soils are then classified into three categories: C (coarse textures of sand, loamy sand, and sandy loam), M (medium textures of loam and silt loam), and F (fine textures of clay loam, silty clay loam, silty clay, and clay).

Organic matter is determined by ashing a 5-gram scoop of sample at 360° C for 2 hours in a muffle furnace. The loss by weight during this ignition is calculated as the organic matter. Results are reported as percent by weight in the soil.

Soil pH and Lime Requirement

The pH is determined using a glass and reference electrode with a pH meter on a 1:1 suspension (5-gram scoop of soil to 5 milliliters water). The water soil mixture is stirred vigorously for 5 seconds and then let stand for 10 minutes before reading. Samples of mineral soils with pH values of less than 6.0 are analyzed further using the following lime requirement test.

The SMP buffer index (lime requirement test) is determined by adding 10 milliliters of buffer solution to the above 1:1 sample. The buffer index of the suspension is determined with a pH meter, after the sample has been stirred intermittently for 15 minutes.

Extractable Phosphorus

Bray-P1 Method—The soil phosphorus measured is that which is extracted by a solution consisting of 0.025 normal HCl and 0.03 normal NH_4F, referred to as Bray-P1 extractant. A 1-gram scoop of soil and 10 milliliters of extractant are shaken for 5 minutes. The amount of phosphorus extracted is determined by measuring the intensity of the blue color developed in the filtrate when treated with ammonium molybdate-sulfuric acid solution and then ascorbic acid solution. The color is measured with a fiberoptic probe colorimeter at 880 nm. The result is reported in parts per million (ppm) phosphorus (P) in the soil.

Olsen-P Method—For highly calcareous soils (pH greater than 7.4), the Olsen-P sodium bicarbonate method is used. A 1-gram scoop of soil and 20 milliliters of 0.5 molar sodium bicarbonate ($NaHCO_3$) solution are shaken for 30 minutes. Blue color in the filtered extract is developed with successive additions of an ammonium molybdate-sulfuric acid solution and then an ascorbic acid solution and measured with a fiberoptic probe colorimeter at 880 nm. Results are reported as parts per million (ppm) phosphorus (P) in the soil.

Exchangeable Potassium

Potassium is extracted from the soil by mixing 10 milliliters of one normal, neutral, ammonium acetate with a 1-gram scoop of soil and shaking for 5 minutes. The exchangeable potassium is measured by analyzing the filtered extract on an atomic absorption spectrophotometer set on emission mode at 766.5 nm. The results are reported as parts per million (ppm) potassium (K) in the soil.

Soluble Salts

Soil samples are evaluated for salinity by first determining the electrical conductivity of a 1:1 suspension. Three 10-gram scoops of soil and 30 milliliters of deionized water are measured into large test tubes and shaken for 30 minutes. The electrical conductivity of this slurry is determined with a dip cell and conductivity meter, and reported as millimhos per centimeter (mmhos/cm).

Slightly to strongly saline soils (conductivity more than 0.9 millimhos) are subjected to a more precise test. A saturated soil paste is prepared by slowly adding deionized water to about 150 grams of soil until the mixture is a thick paste. After an equilibration time of 2 hours, the saturation paste is filtered under suction. The electrical conductivity is determined on the filtrate with a conductivity meter and reported as millimhos per centimeter (mmhos/cm).

Extractable Sulfur

Readily soluble and adsorbed sulfates are extracted with a monocalcium phosphate [$Ca(H_2PO_4)_2$] solution containing 500 ppm of phosphorus. A 10-gram scoop of soil is treated with 25 milliliters of extracting solution and shaken for 30 minutes. The sulfate content in the filtrate is determined turbidimetrically by the addition of $BaCl_2$. The results are reported as parts per million (ppm) of extractable sulfur (S) in the soil.

Extractable Zinc, Copper, Iron, and Manganese

Zinc, copper, iron, and manganese (Zn, Cu, Fe, and Mn) are determined by treating a 10-gram scoop of soil with 20 milliliters of DTPA extracting solution (0.005 molar DTPA, 0.1 molar TEA, and 0.01 molar $CaCl_2$, adjusted to pH 7.3). After shaking for 2 hours, the extract is filtered and the filtrate analyzed for metals with an inductively coupled plasma atomic emission spectrometer (ICP-AES). The results are reported as parts per million (ppm) for each metal in soil.

Nitrate-Nitrogen

Nitrate-nitrogen is determined by adding 60 milliliters of 0.01 *M* $CaCl_2$ extracting solution to a 2-gram scoop of soil and shaking for 15 minutes. The nitrate level in the filtered extract is measured on a continuous flow analyzer by the cadmium reduction method. The results are reported as pounds per acre (lb/A) of nitrate-nitrogen (NO_3-N) in the top 2 feet of soil, or as parts per million (ppm) nitrate-nitrogen (NO_3-N) in the soil for all other depths.

Hot Water Extractable Boron

A 10-gram scoop of soil and 20 milliliters of 0.1% $CaCl_2 \cdot 2H_2O$ (calcium chloride) solution are boiled in a metal container for 5 minutes under reflux using a fiber digestion condenser apparatus. Boron in the filtered extract is determined with an inductively coupled plasma atomic emission spectrometer (ICP-AES). The results are reported as parts per million (ppm) boron (B) in the soil.

Exchangeable Calcium and Magnesium

Calcium and magnesium are extracted from the soil by mixing 10 milliliters of one normal, neutral, ammonium acetate with a 1-gram scoop of soil and shaking for 5 minutes. The filtered extract is analyzed with an inductively coupled plasma atomic emission spectrometer (ICP-AES) for calcium and magnesium. The results are reported in parts per million (ppm) calcium (Ca) and magnesium (Mg) in the soil.

Diagnosing Nutrient Deficiency and Toxicity Symptoms in Fruit and Vegetable Crops

The following list describes general symptoms associated with nutrient disorders in plants. It should be remembered that nutrient deficiencies or toxicities can resemble nonnutritional disorders such as disease or herbicide damage. Use of soil and/or tissue analysis may help confirm whether symptoms are nutritional. More detailed information on determining nutrient disorders based on visual symptoms can be found at: http://www.extension.umn.edu/distribution/horticulture/M1190.html.

Nitrogen (N): Deficiency—Leaves turn pale green to yellow. Oldest leaves are affected first, but in severe cases the whole plant may be yellow. Growth is usually stunted. Occurs most frequently on sandy soils. **Excess**—Nitrogen excess can occur with high rates of nitrogen fertilizer. The result is usually excessive vegetative growth and poor fruit growth.

Phosphorus (P): Deficiency—Leaves appear reddish-purple. Oldest leaves are affected first. Plant growth is stunted. Common in acid and alkaline soils or those soils low in native phosphorus. Frequently occurs on cool wet soils in the spring; however, plants may grow out of phosphorus deficiency as soil warms. **Excess**—High rates of phosphorus fertilizer may induce zinc or iron deficiency.

Potassium (K): Deficiency—Leaves develop gray or tan areas near the margins. Oldest leaves are affected first with characteristic symptoms of scorching around the leaf margins. Occurs on sandy soils and soils low in native potassium. **Excess**—High rates of potassium fertilizer can cause salt burn. Soils with high potassium levels can induce magnesium deficiency on sandy soils.

Calcium (Ca): Deficiency—Growing points of plant may die. Younger leaves are affected. Root tips die and root growth is slow. Tipburn of cabbage, cauliflower, lettuce; black heart of celery; and blossom end rot of tomatoes are due to localized calcium deficiency within the plant. These disorders may occur on high calcium soils. Calcium deficiency may occur on acid and/or dry soils. **Excess**—Not known to occur in Minnesota.

Magnesium (Mg): Deficiency—Oldest leaves turn yellow between the veins. In severe cases, younger leaves may be affected and older leaves may drop off. May occur on acid soils, sandy soils, or soils with high potassium levels. **Excess**—Not known to occur in Minnesota.

Sulfur (S): Deficiency—Symptoms of sulfur deficiency are similar to nitrogen deficiency except that youngest leaves are usually affected first. Can occur on sandy soils low in organic matter. **Excess**—Rare, usually associated with saline conditions.

Boron (B): Deficiency—Usually occurs on younger plant tissue. Growing points die and leaves appear distorted. May cause hollow stem and internal browning in cauliflower and broccoli; cracked stem in celery; internal browning in beets and turnips. Can occur on sandy soils in crops with a high boron requirement. **Excess**—Boron can be highly toxic to some plants at low levels. Avoid excess boron applications. Toxicity symptoms usually occurs on oldest leaves as a scorching of the margins.

Chlorine (Cl): Deficiency—Rare. Not known to occur in the field. **Excess**—Marginal scorch of older leaves. Can occur on salt-affected soils, near streets where deicing salt is used, or when excessive rates of fertilizer containing chlorine are used.

Copper (Cu): Deficiency—Yellowing or dieback of youngest leaves. Sometimes yellowing between the veins. Most copper deficiencies occur on organic soils (peats or mucks). **Excess**—Can occur due to continuous use of copper-containing fungicides. May induce iron chlorosis and cause stunted root systems.

Iron (Fe): Deficiency—Yellowing between the veins on youngest leaves; veins remain green (often referred to as interveinal chlorosis). Occurs frequently on high pH soils (pH greater than 7.2). Some plant species more susceptible than others. With acid-loving plants (e.g., blueberry), chlorosis may occur at a pH as low as 5.5-6.0. **Excess**—Rare. High levels of iron may induce manganese deficiency.

Manganese (Mn): Deficiency—Similar to iron deficiency. Yellowing between the veins of youngest leaves. Usually only the main veins remain green causing a fishbone-like appearance. In some plants older leaves may develop gray streaks or dots. Occurs on high pH soils (pH greater than 7.2). Can also occur on organic soils with pH greater than 6.0. **Excess**—Manganese toxicity can occur on acid soils (pH less than 4.5) or after heat sterilization of greenhouse soils. Excess symptoms include brown spots on leaves and chlorosis (yellowing).

Molybdenum (Mo): Deficiency—Pale distorted narrow leaves. Causes "whiptail" of cauliflower. Can occur on acid soils (pH less than 5.0). **Excess**—Rare.

Nickel (Ni): Deficiency–Small, wrinkled and sometimes cupped leaves; necrotic leaf margins; shortened internodes resulting in stunted plants and witches-broom appearance; referred to as "mouse-ear" disorder in some plants. Occurs in peat-based potting mixes and is accentuated by excess zinc. **Excess**–induces iron and zinc deficiency.